Journal of Asia-Pacific Biodiversity 8 (2015) 343–348

HOSTED BY

ELSEVIER

Contents lists available at ScienceDirect

Journal of Asia-Pacific Biodiversity

journal homepage: http://www.elsevier.com/locate/japb

Journal of Asia-Pacific Biodiversity

Original article

Response of ground arthropods to effect of urbanization in southern Osaka, Japan

Cheol Min Lee [a,*], Tae-Sung Kwon [b]

[a] *Forest and Climate Change Adaptation Laboratory, Center for Forest and Climate Change, Korea Forest Research Institute, Seoul, South Korea*
[b] *Division of Forest Insect Pests and Diseases, Korea Forest Research Institute, Seoul, South Korea*

ARTICLE INFO

Article history:
Received 1 October 2015
Received in revised form
20 October 2015
Accepted 21 October 2015
Available online 1 November 2015

Keywords:
Armadillidiidae
ground arthropods
Isopoda
southern Osaka
urbanization

ABSTRACT

Ground arthropods are abundant in urban ecosystem, but our understanding of their ecological traits is limited. The aim of this study is to clarify the effect of urbanization on ground arthropod communities. Ground arthropods were monitored weekly at six sites (Site 1: Yamato River riverbank; Site 2: Daisen Park; Site 3: Oizumi Ryokuchi Park; Site 4: Osaka Prefecture University campus; Site 5: paddy field; and Site 6: town forest) from April 2005 to December 2005. A total of 221,000 individuals of ground arthropods belonging to 19 orders were identified in the dataset. Isopoda, including Porcellionidae and Armadillidiidae, was the first dominant order and 195,161 individuals were collected, representing 88.3% of the total. The mean density of ground arthropods in Sites 1–4, urbanized areas, was much higher than that in paddy field and town forest. The pattern of ground arthropod community in riverbank did not differ from those of urban park, urban forest area, and university campus. Our findings showed that ground arthropods tend to increase biomass in urban areas and some specific groups in areas urbanized and disturbed by human activities.

Introduction

The nature of ecosystems in the vicinity of urban areas is undermined due to the expansion of cities, and such ecosystems are continuously disturbed by human activities (McKinney 2002; Alaruikka et al 2003). Habitats of wild animals have rapidly deteriorated, as they have disappeared, fragmented, or isolated during urbanization and their populations have become extinct locally (McIntyre et al 2001; McKinney 2008; Lee and Kwon 2013; Lee et al 2015). Urbanization and its impact are one of the most critical challenges that humans are facing (Magura et al 2013). The urban population worldwide increased from 746 million in 1950 to 3.9 billion in 2014, and 2.5 billion people will be added to the population by 2050 (United Nations 2014).

The study of biotic communities on urban ecosystems is important for evaluating the impact of urbanization on wild animal habitats and preserving biodiversity in urban areas (Niemelä et al 2000; George and Crooks 2006; Rubèn and Ian 2009; Sattler et al 2011). It is essential to understand how urbanization affects species richness, species composition, populations, and communities, because changes in community attributes influence the structures and functions of ecosystems (Bang and Faeth 2011). Ground arthropods are sensitive to disturbance caused by humans and biological and nonbiological environmental changes because they have a relatively short lifecycle (McKinney 2008; Magura et al 2013). Many ground arthropods have limited mobility, are closely related to vegetation and soil environment, and play the roles of consumers, detritivores, carnivores, parasites, and herbivores. Therefore, ground arthropods are considered to be an ideal indicator for evaluating urbanization (McIntyre 2000; Magura et al 2008; Bang and Faeth 2011). Many studies on the impact of urbanization are usually conducted at the species level such as Isopoda, Carabidae, Cerambycidae, and Araneae (Gaublomme et al 2008; Lee and Ishii 2009; Sattler et al 2011; Lee and Kwon 2013; Magura et al 2013). However, studies on responses of the entire ground arthropods communities were not enough (McIntyre et al 2001; Bang and Faeth 2011). Therefore, this study conducted a survey at a riverbank, urban park, urban forest area, paddy field, university campus, and town forest in southern Osaka. The impact

* Corresponding author.
E-mail address: leecheolmin77@gmail.com (C.M. Lee).

Peer review under responsibility of National Science Museum of Korea (NSMK) and Korea National Arboretum (KNA).

http://dx.doi.org/10.1016/j.japb.2015.10.007
pISSN2287-884X eISSN2287-9544/

of urbanization on ground arthropods was discussed based on our findings.

Materials and methods

Study sites

The survey was conducted using pitfall traps in the six areas: Yamato River riverbank (Site 1), Daisen Park (Site 2), Oizumi Ryokuchi Park (Site 3), Osaka Prefecture University campus (Site 4), paddy field (Site 5), and town forest (Site 6) (Figure 1). The overview of vegetation and environment of each site is as follows:

Site 1 (Yamato River riverbank) is located on the riverbank of both sides on Kyouki bridge over the Yamato River (left bank: Matsubara City; right bank: Osaka City). A total of 20 traps were set up on the left bank: 10 in the vegetation area dominated by *Phragmites karka* and *Salix* sp. and 10 in the recreation ground with a wide vacant lot. In the right bank, 20 traps were set up in an area dominated by herbs such as *Arundinella hirta* and *Cayratia japonica*.

Site 2 (Daisen Park), a green area of about 35 ha, is located in Sakai city close to Nintoku Royal Tomb, which is interspersed with small ancient tombs. A total of 50 traps were set up in Site 2: 10 in a grassland dominated by herbs such as *Acer buergerianum* and *Digitaria ciliaris*; 10 in a *Phyllostachys pubescens* forest; 10 in an area where *Quercus glauca*, *Quercus serrata*, and *Quercus myrsinaefolia* are vegetated; 10 in a grassland where deciduous trees such as *Pterocarya rhoifolia* are vegetated and dominated by *Solidago altissima*; and 10 in an area where deciduous trees such as *Rhododendron hirado azarea* and *Prunus jamasakura* are vegetated.

Site 3 (Oizumi Ryokuchi Park), an urban open space of about 88 ha, is located in eastern Sakai city and southwestern Matsubara city, and 300,000 trees belonging to about 200 species are vegetated. A total of 40 traps were set up: 10 in a lawn where *Euonymus japonica* is planted, 10 in a grassland where deciduous trees such as *A. buergerianum* are planted and dominated by herbs such as *C. japonica*, 10 in a *Q. glauca* forest, and 10 in an area where *Ulmus parvifolia* and *Zelkova serrata* are vegetated and dominated by herbs such as *Setaria viridis*.

Site 4 (Osaka Prefecture University campus), a university campus of about 49 ha, is located at the central part of Sakai city and composed of a rice paddy, an orchard, and a pond. A total of 40 traps were set up: 10 in an area where deciduous trees such as *Pterocarya stenoptera* and evergreens such as *Q. glauca* are vegetated, 10 in a lawn where a couple of *Zelkova serrata* are vegetated, 10 in an area where deciduous trees such as *Ginkgo biloba* are vegetated and dominated by herbs and short rice such as *D. ciliaris*, and 10 in an area adjacent to a vineyard (*Vitis* sp.) and dominated by short herbs such as *Persicaria longiseta*.

Site 5 (paddy field) is a rice paddy located at Tomikura area in southern Sakai city. It is dotted with secondary forests dominated by *Q. glauca*, and rice is cultivated from April to September. A total of 30 traps were set up in four places in the rice paddy, and two places between secondary forests and the rice paddy.

Site 6 (town forest), dominated by *Quercus serrata* and *Quercus acutissima*, is an area located at Hachigamine area in southern Sakai city and adjacent to town forest and rice paddy where *Pleioblastus chino* var. *viridis* is vegetated at a forest floor. A total of 40 traps were set up: 20 at forest edges of the town forest and 20 in the rice paddy.

Survey method

The survey was carried out from April 2012 to December 2012 using pitfall traps. A plastic cup (diameter 7 cm, depth 10 cm) was used to make a trap without using any bait, and five holes were made to avoid rainwater. The traps were set up in a row at intervals of 5 m at each survey site, and their opening parts were set at the same height from the ground. They were set for a week and surveyed for a total of 38 times at each survey site. As some traps were lost during the survey, 1392, 1370, 1084, 1349, 1063, and 1488 traps were collected from Sites 1–6.

This study identified every ground arthropod up to the order level and up to the family level for Stylommatophora, Isopoda, Hymenoptera, and Coleoptera. In this study, to evaluate biomass (dry weight), ground arthropods were dried at 60°C for 48 hours using an air dryer (Samyang, Osaka, Japan), and an automatic scale (A and D, HR-60, precision = 0.1 mg) was used to measure the weight.

Land-use pattern

A 1:5000 scale map published in 2001 by the Geospatial Information Authority of Japan was used to analyze the surrounding

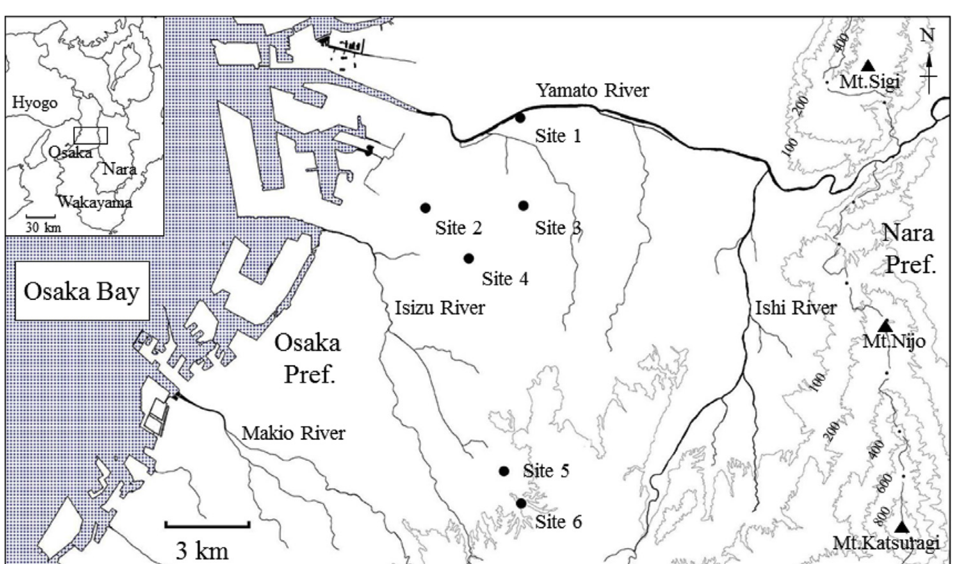

Figure 1. Location of six study sites in southern Osaka.

Table 1. Mean density (number of individuals per 10 traps) of ground arthropods collected at six study sites in southern Osaka

Species	Dry weight (N, average ± SE)	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Whole site
Stylommatophora		0.45 (63)	0.24 (33)	0.43 (47)	1.08 (146)	0.11 (12)	0.08 (12)	0.40 (313)
Clausiliidae	11, 0.014 ± 0.002	0.34 (48)	0.14 (19)	0.03 (3)	0.01 (2)	0.11 (12)	0.07 (11)	0.12 (95)
Philomycidae	10, 0.069 ± 0.005	0.11 (15)	0.10 (14)	0.41 (44)	1.07 (144)	—	0.01 (1)	0.28 (218)
Araneae	30, 0.034 ± 0.002	2.87 (399)	1.93 (264)	1.36 (147)	2.59 (350)	1.78 (189)	2.16 (321)	2.16 (1670)
Isopoda		322.23 (44,855)	352.93 (48,351)	426.79 (46,264)	407.63 (54,989)	2.28 (242)	3.09 (460)	251.98 (195,161)
Porcellionidae	30, 0.034 ± 0.002	77.90 (10,843)	12.36 (1694)	8.83 (957)	27.15 (3662)	0.39 (41)	1.98 (294)	22.58 (17,491)
Armadillidiidae	30, 0.034 ± 0.002	244.34 (34,012)	340.56 (46,657)	417.96 (45,307)	380.48 (51,327)	1.89 (201)	1.12 (166)	229.40 (177,670)
Amphipoda	30, 0.004 ± 0.0003	1.61 (224)	—	—	0.10 (14)	—	—	0.31 (238)
Julida	7, 0.019 ± 0.003	0.01 (2)	0.01 (1)	—	0.01 (1)	0.15 (16)	0.93 (139)	0.21 (159)
Polydesmida	23, 0.07 ± 0.017	0.22 (30)	1.10 (151)	2.82 (306)	0.30 (41)	0.11 (12)	1.26 (188)	0.94 (728)
Scutigeromorpha	5, 0.004 ± 0.002	0.01 (2)	0.09 (13)	0.01 (1)	0.04 (5)	0.02 (2)	0.01 (2)	0.03 (25)
Scolopendromorpha	10, 0.042 ± 0.008	0.11 (15)	0.12 (16)	0.05 (5)	0.08 (11)	0.04 (4)	0.09 (14)	0.08 (65)
Lithobiomorpha	2, 0.002 ± 0.0002	0.01 (2)	0.03 (4)	0.02 (2)	0.01 (1)	0.01 (1)	0.06 (9)	0.02 (19)
Thysanura	1, 0.001	—	—	—	0.01 (1)	—	0.05 (8)	0.01 (9)
Blattodea	1, 0.01	—	0.28 (38)	0.05 (5)	—	—	—	0.06 (43)
Orthoptera	10, 0.111 ± 0.025	0.65 (91)	0.07 (10)	0.92 (100)	0.16 (22)	0.13 (14)	0.03 (5)	0.31 (242)
Phasmida	1, 0.02	—	—	—	—	—	0.01 (1)	0.001 (1)
Dermaptera	30, 0.043 ± 0.013	0.71 (99)	2.72 (373)	3.15 (341)	1.90 (256)	0.05 (5)	0.07 (10)	1.40 (1084)
Hemiptera	30, 0.013 ± 0.003	1.26 (175)	1.18 (162)	1.39 (151)	0.47 (64)	0.65 (69)	0.15 (23)	0.83 (644)
Neuroptera	4, 0.017 ± 0.002	—	0.04 (5)	0.01 (1)	0.01 (2)	—	0.01 (1)	0.01 (9)
Hymenoptera		6.85 (953)	7.03 (963)	3.93 (426)	5.92 (799)	5.84 (620)	3.48 (518)	5.52 (4279)
Formicidae	13, 0.0005 ± 0.0001	6.85 (953)	7.03 (963)	3.93 (426)	5.92 (799)	5.84 (620)	3.48 (518)	5.52 (4279)
Lepidoptera	12, 0.053 ± 0.008	1.70 (236)	0.28 (39)	0.39 (42)	0.51 (69)	0.13 (14)	0.32 (47)	0.58 (447)
Coleoptera		17.13 (2384)	16.87 (2311)	54.43 (5900)	16.25 (2192)	12.59 (1337)	11.69 (1740)	20.48 (15,864)
Carabidae	30, 0.068 ± 0.017	8.33 (1160)	3.91 (535)	5.90 (640)	4.16 (561)	4.37 (464)	10.24 (1524)	6.31 (4884)
Brachinidae	30, 0.084 ± 0.004	0.37 (51)	—	1.53 (166)	0.09 (12)	0.02 (2)	0.05 (8)	0.31 (239)
Dytiscidae	1, 0.001	—	—	—	—	0.02 (2)	—	0.003 (2)
Hydrophilidae	1, 0.003	—	—	—	—	0.06 (6)	—	0.01 (6)
Histeridae	30, 0.027 ± 0.01	0.05 (7)	0.15 (21)	0.65 (71)	0.04 (6)	1.34 (142)	—	0.32 (247)
Silphidae	30, 0.09 ± 0.005	0.04 (5)	0.07 (10)	24.16 (2619)	0.07 (10)	—	0.04 (6)	3.42 (2650)
Staphylinidae	30, 0.016 ± 0.003	0.80 (112)	1.11 (152)	0.44 (48)	0.70 (94)	0.07 (7)	0.12 (18)	0.56 (431)
Lucanidae	1, 0.034	—	—	—	—	0.01 (1)	0.01 (1)	0.003 (2)
Scarabaeidae	30, 0.018 ± 0.002	2.27 (316)	8.92 (1222)	15.99 (1733)	3.60 (485)	0.64 (68)	0.29 (43)	4.99 (3867)
Elateridae	16, 0.088 ± 0.041	3.18 (443)	0.74 (102)	1.01 (109)	5.84 (788)	0.03 (3)	0.01 (1)	1.87 (1446)
Dermestidae	3, 0.001 ± 0.0001	0.01 (1)	0.04 (6)	0.02 (2)	0.07 (10)	0.05 (5)	0.06 (9)	0.04 (33)
Melyridae	1, 0.005	0.01 (2)	—	—	—	—	0.01 (1)	0.004 (3)
Nitidulidae	4, 0.01 ± 0.005	—	0.08 (11)	0.24 (26)	0.04 (5)	0.01 (1)	0.02 (3)	0.06 (46)
Cryptophagidae	3, 0.001 ± 0.0005	0.01 (1)	0.03 (4)	—	0.09 (12)	—	—	0.02 (17)
Corylophidae	2, 0.002 ± 0.001	—	—	0.01 (1)	—	—	—	0.001 (1)
Endomychidae	3, 0.002 ± 0.0004	0.29 (41)	—	—	—	—	—	0.05 (41)
Coccinellidae	2, 0.008 ± 0.005	0.02 (3)	0.01 (1)	—	0.01 (2)	0.04 (4)	—	0.01 (10)
Tenebrionidae	14, 0.017 ± 0.001	1.31 (182)	1.69 (232)	4.21 (456)	1.41 (190)	5.08 (540)	0.56 (84)	2.17 (1684)
Alleculidae	4, 0.006 ± 0.002	0.01 (1)	—	—	—	0.53 (56)	—	0.07 (57)
Anthicidae	1, 0.002	0.01 (1)	—	0.02 (2)	—	—	—	0.004 (3)
Cerambycidae	1, 0.479	—	—	—	—	—	0.007 (1)	0.001 (1)
Chrysomelidae	2, 0.051 ± 0.02	0.22 (30)	0.01 (1)	0.01 (1)	0.05 (7)	0.02 (2)	0.05 (7)	0.06 (48)
Curculionidae	6, 0.014 ± 0.004	0.15 (21)	0.04 (6)	0.09 (10)	0.07 (10)	0.32 (34)	0.22 (33)	0.15 (114)
Scolytidae	9, 0.0002 ± 0.0001	0.05 (7)	0.06 (8)	0.15 (16)	—	—	0.01 (1)	0.04 (32)
Total number of orders		15	16	15	17	14	17	19
Density (total number of individuals)		355.8 (49,530)	384.9 (52,734)	495.7 (53,738)	437.1 (58,963)	23.9 (2537)	23.5 (3498)	285.3 (221,000)

SE = Standard error.
The total number of individuals collected at each site is shown in parentheses.

environment of each site. The analysis on land use was conducted within 500 m of each site based on its edge. Land use was classified into eight categories: forest, paddy, field, park and green space, river and pond, open space, urban area, and road. Then, the ratio of the total number of pixels of 500 m was calculated by the number of pixels of each category using Adobe Photoshop 7.0 (1990-2005Adobe Systems Incorporated, United States and/or other countries).

Data analysis

Relationships between ground arthropod communities and landscape patterns were investigated with detrended correspondence analyses (Hill and Gauch 1980). We used unconstrained detrended correspondence analyses to consider the complete species data variation and to avoid the problem of local minima occurring in nonmetric multidimensional scaling (Leyer and Wesche 2007). The multiresponse permutation procedure (MRPP) was used for testing the connection between the surrounding environment and community grouping. In the MRPP, a permutation test is conducted to evaluate the differences between or among groups of sample units based on within-group similarities. Correspondence analysis (CA) and Multi-response permutation procedures (MRPP) were conducted using PC-ORD (version 5.17) (McCune and Mefford 1999).

Results

A total of 221,000 individuals of ground arthropods belonging to 19 orders were collected from the six sites at southern Osaka, and the mean density (the number of individuals per 10 traps) was 285.3 (Table 1). Site 3 showed the highest mean density (495.7), followed by 437.1 in Site 4, 384.9 in Site 2, and 355.8 in Site 1, while Site 5 (23.9) and Site 6 (23.5) showed a low mean density. The number of the orders of ground arthropods in each site was in the range of 14–17: 17 in Sites 4 and 6, 16 in Site 2, 15 in Sites 1 and 3, and 14 in Site 5.

Isopoda was the first dominant order with 195,161 (251.98) individuals in all sites, representing 88.3% of the total, followed by Coleoptera (7.2%), Hymenoptera (1.9%), Araneae (0.8%), and Dermaptera (0.5%); and these five orders made up 98.7% of the total individuals. As for Isopoda, Porcellionidae and Armadillidiidae were collected, but the number of the latter was 10 times higher than that of the former. Twenty-four families belonging to Coleoptera were collected, and among them, the number of Carabidae was highest with 4994 individuals (30.8% of Coleoptera), followed by Scarabaeidae (24.4%), Silphidae (16.7%), Tenebrionidae (10.6%), and Elateridae (9.1%). Five dominant families accounted for 91.6% of the total individuals of Coleoptera. Meanwhile, less than 10 individuals of Thysanura, Phasmida, Neuropter, Dytiscidae, Hydrophilidae, Lucanidae, Melyridae, Corylophidae, Coccinellidae, Anthicidae, and Cerambycidae were collected.

The three dominant orders in Sites 1–4 were in the order of Isopoda, Coleoptera, and Hymenoptera, and these three orders accounted for 97–98% of the individuals at each site; however, fourth and fifth orders differed by site: Araneae and Lepidoptera (Site 1), Dermaptera and Araneae (Site 2), Dermaptera and Polydesmidae (Site 3), and Araneae and Dermaptera (Site 4). Meanwhile, the top three orders observed in Sites 5 and 6 were in the order of Coleoptera, Hymenoptera, and Isopoda. The proportion of Isopoda was small, and the proportions of the individuals of the top three orders were smaller with 86.7% (Site 5) and 77.7% (Site 6). Araneae was the fourth dominant order in both Site 5 and Site 6, while the fifth dominant order varied, with Hemiptera in Site 5 and Polydesmida in Site 6; the proportion of the top five orders were 97% and 93%, respectively, in Sites 5 and 6.

The mean density of order or family was calculated using biomass (mean dry weight per 10 traps; Figure 2). Site 3 showed the highest mean biomass with 18.1 g, followed by Site 4 (14.5 g), Site 2 (12.8 g), Site 1 (12.0 g), Site 6 (1.0 g), and Site5 (0.6 g). The tendency of mean biomass was similar to that of the mean density, and sites (Sites 1–4) in urban areas including riverbank and university campus showed a higher amount of biomass, whereas the amount of biomass in paddy field and town forest (Sites 5 and 6) was small. An analysis of land use around study sites using Geographic information system (GIS) showed that urban areas made up the highest proportion of land in Sites 1–4, paddy of Site 5, and forest of Site 6 (Table 2).

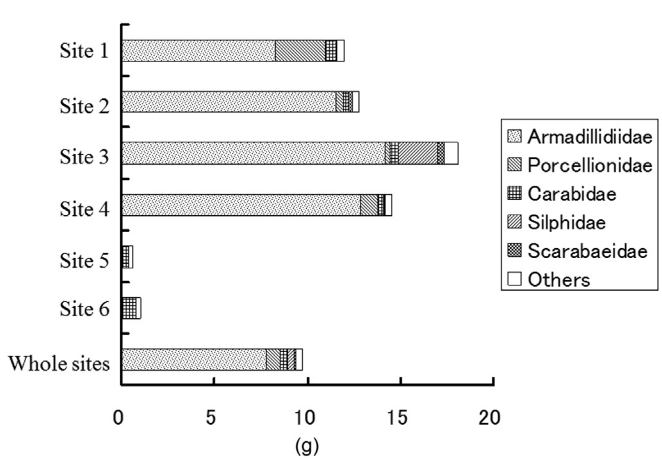

Figure 2. Biomass (density × dry weight) of arthropods collected at six study sites in southern Osaka.

Ordination plots of ground arthropod communities were gathered in Sites 1–4, whereas these were scattered in Sites 5 and 6 (Figure 3). The two axes explained 77.2% and 12.3% of the total variance. The first axis is in a positive correlation with forest ($r = 0.914$), paddy ($r = 0.740$), and field ($r = 0.693$), but in a negative correlation with open space ($r = -0.573$) and urban area ($r = -0.973$). Among arthropods, Armadillididae ($r = -0.963$), Staphylinidae ($r = -0.843$), Dermaptera ($r = -0.812$), Hemiptera ($r = -0.692$), and Scarabaeidae ($r = -0.633$) showed a relatively high negative correlation with the first axis, whereas Lucanidae ($r = 0.999$), Curculionidae ($r = 0.902$), and Julida ($r = 0.746$) showed a positive correlation. A comparison of connectivity by grouping urban park, urban forest area, and university campus (Sites 2, 3, and 4), and riverbank, paddy field, and town forest (Sites 1, 5, and 6) using MRPP showed no statistically significant difference ($A = 0.278$, $p = 0.057$).

Discussion

There was no significant difference in the number of orders of ground arthropods between the sites, but there was a significant difference in biomass. There was greater biomass of ground arthropods in the riverbank, urban park, urban forest area, and university campus, where urbanization occurred, compared to that in the paddy field and town forest. This was because Porcellionidae and Armadillidiidae of Isopoda were abundant in the riverbank, urban park, urban forest area, and university campus. Several previous papers pointed out that disturbances have caused significant changes in community structure, species richness, and abundance of Isopoda (Pitzalis et al 2005; Magura et al 2008). According to the study of Magura et al (2008), urban parks are habitats that the urban environment specialist *Porcellio scaber* prefers to inhabit most, and the abundance of this species was much higher in urban areas than in suburban and rural areas. This species was found only in human residences due to heat island effect and moist shelters, and it is known to have tolerance to heavy metals causing air pollution (Paoletti and Hassall 1999; Magura et al 2008). We did not identify Isopoda up to the species level, but we assume that this species with ecological characteristics shown in the results of previous studies dominates urban areas, and a further study is necessary to identify it up to the species level.

When comparing the ordination plots of ground arthropod communities, the first axis is thought to show the impact of urbanization. In addition, Armadillidiidae, Staphylinidae, Dermaptera, Hemiptera, Lucanidae, and Curculionidae showed relatively high positive and negative correlations with this axis, will increase or decrease according to the impact of urbanization. Magura et al (2013) classified Staphylinidae to the species level, and species richness of Staphylinidae in rural areas was approximately two times smaller than that in urban areas. In addition, as a result of classifying according to ecological characteristics, species richness of forest species, hygrophilous species, saprophilous species, myrmecophilous species, phytodetriticol species, and mycetophilous species was smaller in urban areas than in rural areas, but that of thermophilous species in urban areas was higher than in rural areas. In studies on the impact of urbanization using ground beetles in Japan, Finland, and Belgium, species richness was lower in urban areas than in rural areas (Niemelä et al 2002; Ishitani et al 2003; Gaublomme et al 2008). Although several previous studies were conducted to clarify the impact of urbanization at the species level, this study showed that the order or family level can reveal the impact of urbanization. McIntyre et al (2001) also reported that

Table 2. Area (ha) and percentage of land-use categories within the range of 500 m from the edge of six study sites.

Land-use category	Site 1		Site 2		Site 3		Site 4		Site 5		Site 6	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Forest	0.2	0.2	0	0	0	0	0	0	27.5	16.1	36.4	32.4
Paddy	1.1	0.9	1.3	0.6	43.6	16	9.3	4.1	55.2	32.4	14.8	13.1
Field	3.1	2.4	0.6	0.3	7.2	2.6	8.1	3.6	18.7	11	3.4	3.1
Park and green space	7.2	5.8	69.1	6.9	11.2	4.1	32.8	14.5	0	0	32	28.5
River and pond	24.7	19.8	0	0	9.5	3.5	10.6	4.7	7.3	4.3	4.2	3.7
Open space	12.5	10	13.4	6.2	26.8	9.8	16.1	7.1	12	7	5.4	4.8
Urban area	61.7	49.3	117.3	54.1	150.5	55.2	130.7	57.9	33.1	19.5	7.7	6.8
Road	14.5	11.6	15.2	7	24	8.8	18.3	8.1	16.4	9.7	8.5	7.6
Total	125.1	100	216.8	100	272.8	100	225.9	100	170.1	100	112.4	100

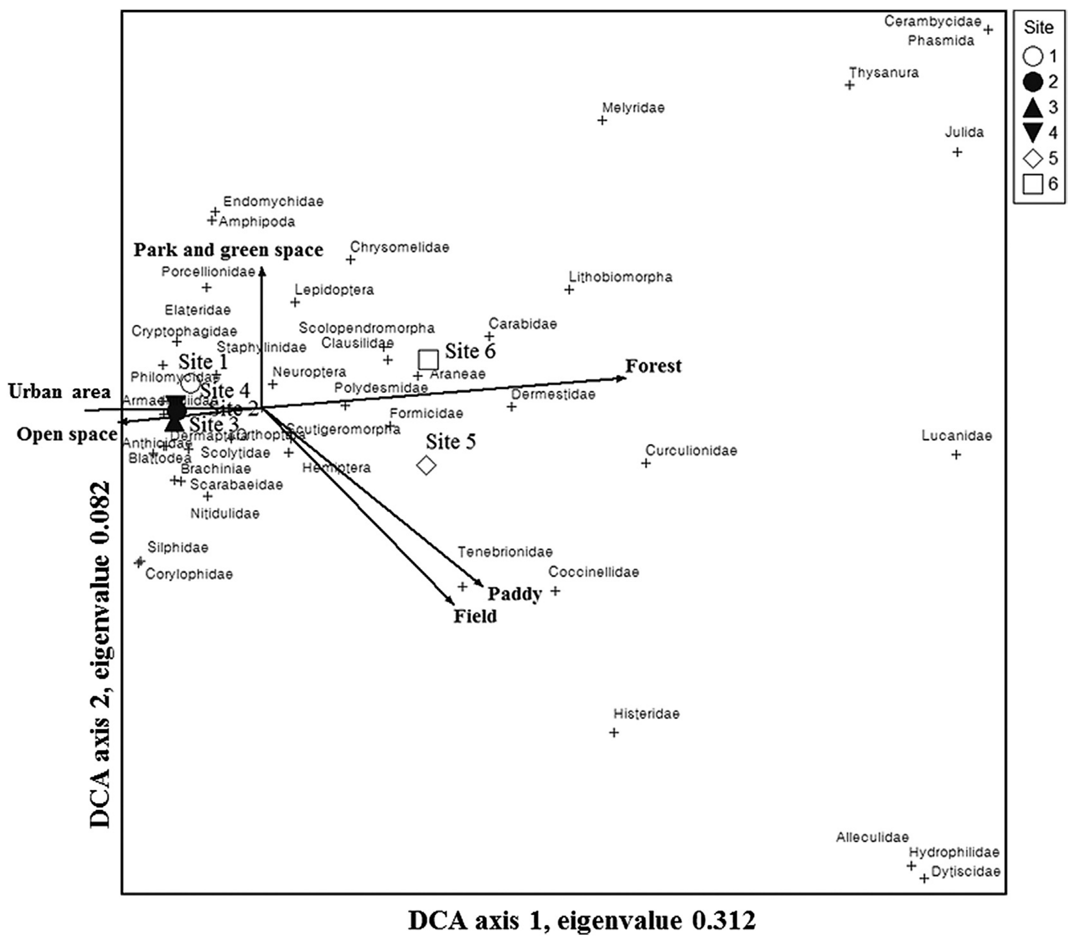

Figure 3. DCA ordination for ground arthropod communities. Vectors indicate environmental factors with an axis correlation $r^2 > 0.6$, except for park and green space. Terms written using small-sized letters indicate family or order names of ground arthropods. DCA = Detrended correspondence analysis.

ground arthropod communities are very diverse according to land use in an urban environment. Classification of the species level requires many studies on taxonomy and ecological characteristics as well as a lot of time and money, whereas classification of the order or family level is relatively easy. In the future, classification of the order or family level will be useful when evaluating urbanization.

As a result of comparing connectivity after classifying riverbank, paddy field, town forest and urban park, urban forest area, and university campus into groups, no significant difference was found. Areas around the riverbank of Yamato River were almost residential areas. The connectivity of an urban open space or park with surrounding natural green areas is a very important issue because it is a crucial factor for maintaining and preserving the diversity of arthropods in urban areas. However, the finding that there was no significant difference between ground arthropod communities in the riverbank and those in urban areas was beyond our expectations, despite the unique connectivity of rivers. In a study on ground beetles in the same area (Lee and Ishii 2009), species richness of forest, open-habitat specialist, large-sized, and endemic species decreased according to the impact of urbanization. Therefore, specialist species that prefer a specific environment decrease and generalist species that adapt to a disturbed environment become dominant as urbanization increases. There are a limited number of species that can adapt to such an urban environment because the composition of ecosystems in urban areas is people centered. Our findings suggest that it is necessary to maintain the diversity of land, including paddy field, farmland, and remnant forest regions, to preserve biodiversity in urban areas.

Acknowledgments

We wish to express our sincere thanks to Professors M. Ishii and N. Hirai (Osaka Prefecture University), and T. Hirowatari (Kyushu University) for their kind help and suggestion during the survey.

References

Alaruikka D, Kotze DJ, Matveinen K, et al. 2003. Carabid beetle and spider assemblages along a forested urban–rural gradient in southern Finland. *Journal of Insect Conservation* 6:195–206.
Bang C, Faeth SH. 2011. Variation in arthropod communities in response to urbanization: seven years of arthropod monitoring in a desert city. *Landscape and Urban Planning* 103:383–399.
Gaublomme E, Hendrickx F, Dhuyvetter H, et al. 2008. The effects of forest patch size and matrix type on changes in carabid beetle assemblages in an urbanized landscape. *Biological Conservation* 141:2585–2596.
George SL, Crooks KR. 2006. Recreatin and large mammal activity in an urban nature reserve. *Biological Conservation* 133:107–117.
Hill MO, Gauch HG. 1980. Detrended correspondence analysis: an improved ordination technique. *Vegetatio* 42:47–58.
Ishitani M, Kotze DJ, Niemelä J. 2003. Changes in carabid beetle assemblages across an urban–rural gradient in Japan. *Ecography* 26:481–489.
Lee CM, Ishii M. 2009. Species diversity of ground beetle assemblages at urban greeneries in southern Osaka, central Japan. *Japanese Society of Environmental Entomology and Zoology* 20:47–58.
Lee CM, Kwon TS. 2013. Community structure, species diversity of insect (ants, ground beetle), and forest health in Hongneung Forest. *Journal of Korean Forest Society* 102:97–106.
Lee CM, Park JW, Kwon TS, et al. 2015. Diversity and density of butterfly communities in urban green areas: an analytical approach using GIS. *Zoological Studies* 54:4.
Leyer I, Wesche K. 2007. *Multivariate Statistik in der Ökologie*. Berlin: Springer.
Magura T, Hornung E, Tóthmérész B. 2008. Abundance patterns of terrestrial isopods along an urbanization gradient. *Community Ecology* 9:115–120.
Magura T, Nagy D, Tóthmérész B. 2013. Rove beetles respond heterogeneously to urbanization. *Journal of Insect Conservation* 17:715–724.
McCune B, Mefford M. 1999. *PC-ORD. Multivariate analysis of ecological data*. Vers. 4.0. Gleneden Beach, OR: MjM Software Design.
McIntyre NE, Rango J, Fagan WF, et al. 2001. Ground arthropod community structure in a heterogeneous urban environment. *Landscape and Urban Planning* 52:257–274.
McIntyre NE. 2000. Ecology of urban arthropods: a review and a call to action. *Annals of the Entomological Society of America* 93:825–835.
McKinney ML. 2002. Urbanization, biodiversity, and conservation. *Bioscience* 52:883–890.
McKinney ML. 2008. Effects of urbanization on species richness: a review of plants and animals. *Urban Ecosystem* 11:161–176.
Niemelä J, Kotze DJ, Venn S, et al. 2002. Carabid beetle assemblages (Coleoptera, Carabidae) across urban–rural gradients: an international comparison. *Landscape Ecology* 17:387–401.
Niemelä J, Kotze J, Ashworth A, et al. 2000. The search for common anthropogenic impacts on biodiversity: a global network. *Journal of Insect Conservation* 4:3–9.
Paoletti MG, Hassall M. 1999. Woodlice (Isopoda: Oniscidae): their potential for assessing sustainability and use as bioindicators. *Agriculture Ecosystems and Environment* 74:157–165.
Pitzalis M, Fattorini S, Trucchi E, et al. 2005. Comparative analysis of species diversity of Isopoda Oniscidae and Collembola communities in burnt and unburnt habitats in central Italy. *Italian Journal of Zoology* 72:127–140.
Rubèn OA, Ian MF. 2009. Living in the big city: effects of urban land-use on bird community structure, diversity, and composition. *Landscape and Urban Planning* 90:189–195.
Sattler T, Obrist MK, Duelli P, et al. 2011. Urban arthropod communities: added value or just a blend of surrounding biodiversity? *Landscape and Urban Planning* 103:347–361.
United Nations. 2014. *World urbanization prospects: the 2014 revision*. Available at: http://esa.un.org/unpd/wup/index.htm [Date accessed: 6 November 2015].